

Integrating Human Factors into Crew Exploration Vehicle (CEV) Design

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Background/ Purpose

Crew Exploration Vehicle (CEV)

- NASA's new Vision for Exploration
 - Send humans beyond Earth orbit
- It is critical to consider the human as a system
 - Demand early and continuous user involvement
 - Iterative “prototype/test/redesign” process
 - Cost savings since human/system issues identified early
- NASA/Prime Contractor human engineering (HE) team formed for Crew Exploration Vehicle (CEV)
 - Apply HE requirements and guidelines to hardware/software
 - Provide HE design, analysis and evaluation of crew interfaces

- Requirements development
- Mission-level task analysis
- Many practice-orientated evaluations using low-fidelity CEV mock-ups:
 - Crew module internal layout in terms of seats, display and control panel and other systems/ sub-systems
 - Window size and location
 - Validation of HE requirement on Net Habitable Volume (NHV)

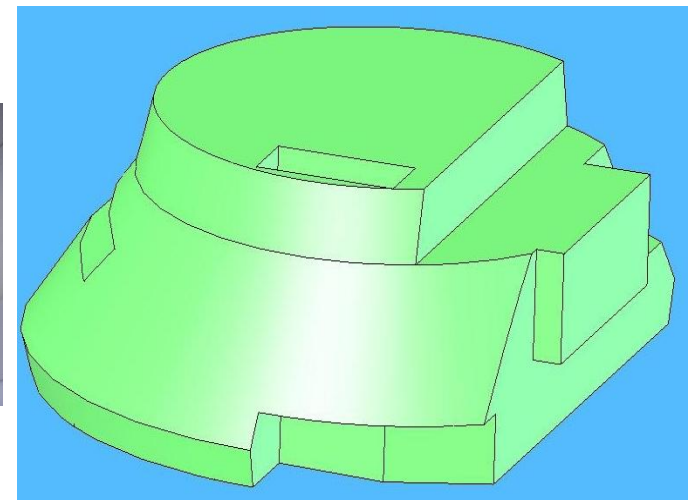
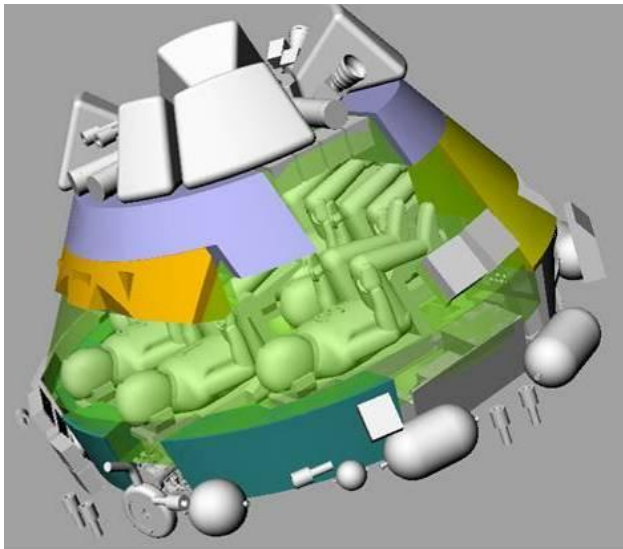




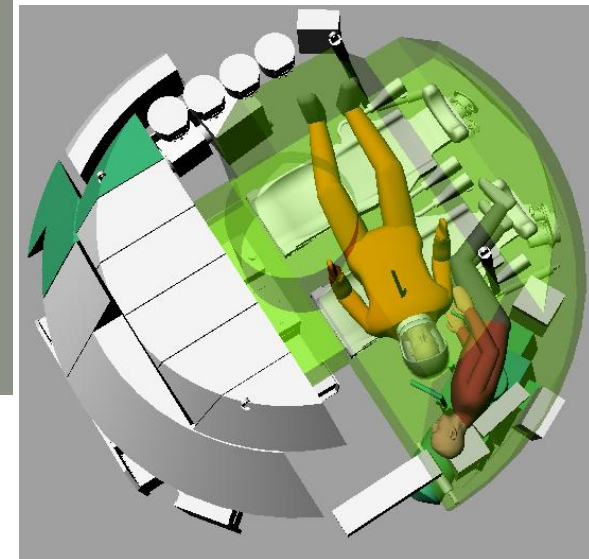

	Forward Window 1	Forward Window 2	Forward Window 3	Forward Window 4	Forward Window 5
Rating Scale: 4 = Highly Satisfactory 3 = Satisfactory 2 = Unsatisfactory 1 = Highly Unsatisfactory 0 = Not Rated					
	vertical window	Circular window	Curved window	Horizontal window	Apollo window
Forward Window Configuration Ratings					
1. Rate the overall situational awareness of horizon during this phase of flight for each window configuration					
2. Rank order windows from 1 to 5 for viewing needs during this phase of flight (1 = 1st choice)					
3. Does the current mirror aid situational awareness during this phase of flight for each window? (Y/N)					
General Forward Window comments (e.g. shape, size, any obstruction concerns)					



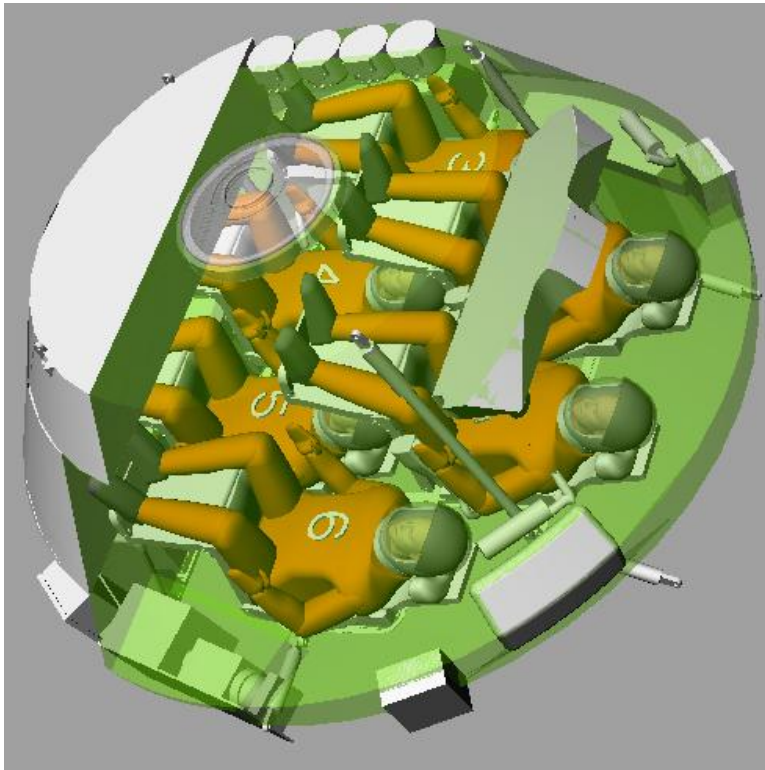
- Definition of Net Habitable Volume (NHV):
“Total remaining pressurized volume available to on-orbit crew after accounting for the loss of volume due to deployed hardware and structural inefficiencies which decrease functional volume.”
- Purpose of the Study:
 - Develop and validate requirements providing sufficient CEV NHV for crewmembers to live and perform tasks in support of mission goals
 - Develop a standard NHV calculation method using computer models and physical mockups
 - ➡ • Measure and validate sufficiency of NHV for the current design concepts via computer modeling and crew/ stakeholder evaluations



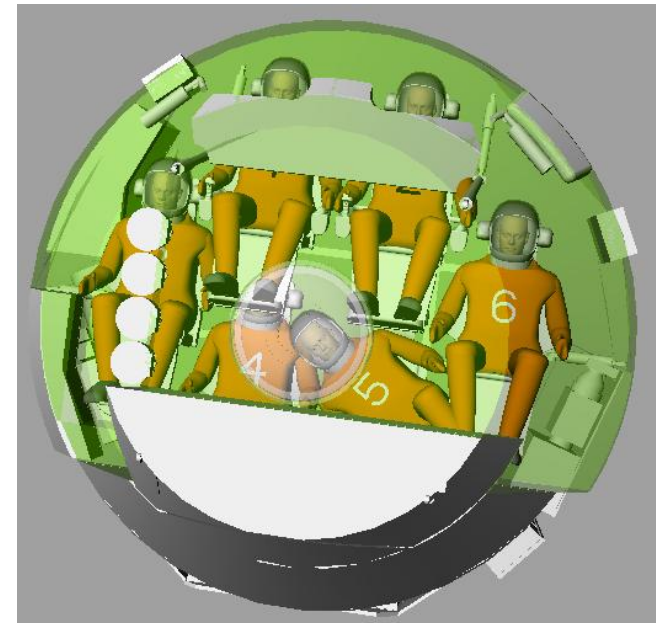
- Crew of 2, 4 and 6
 - Worst case: all 99th percentile male astronauts
- Selected critical on-orbit tasks such as:
 - Ascent/descent
 - Post insertion activities
 - Seat egress
 - Suit doff and stow
 - Waste hygiene usage
 - Sleeping/ eating
 - Cargo transfer
 - Docking/rendezvous



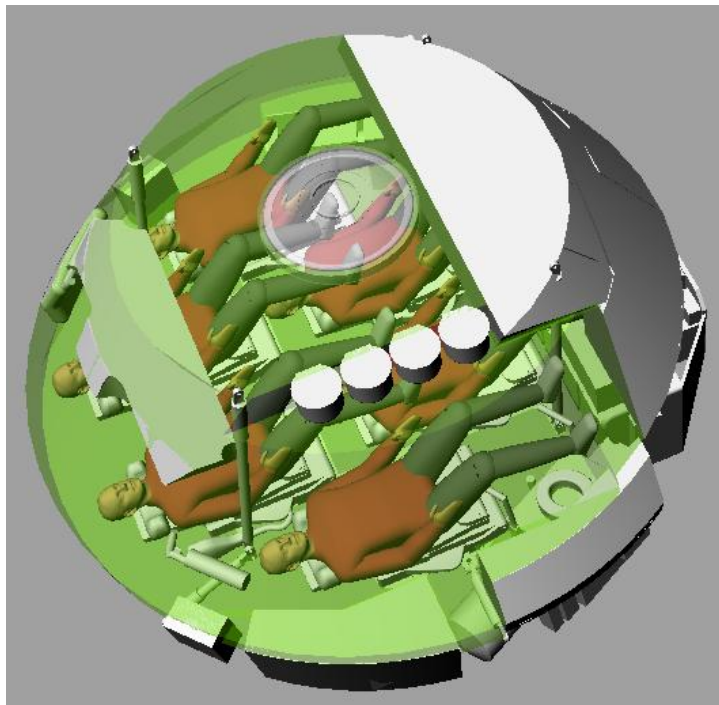
Ascent / Descent – Crew is suited and seats are in the full upright position.



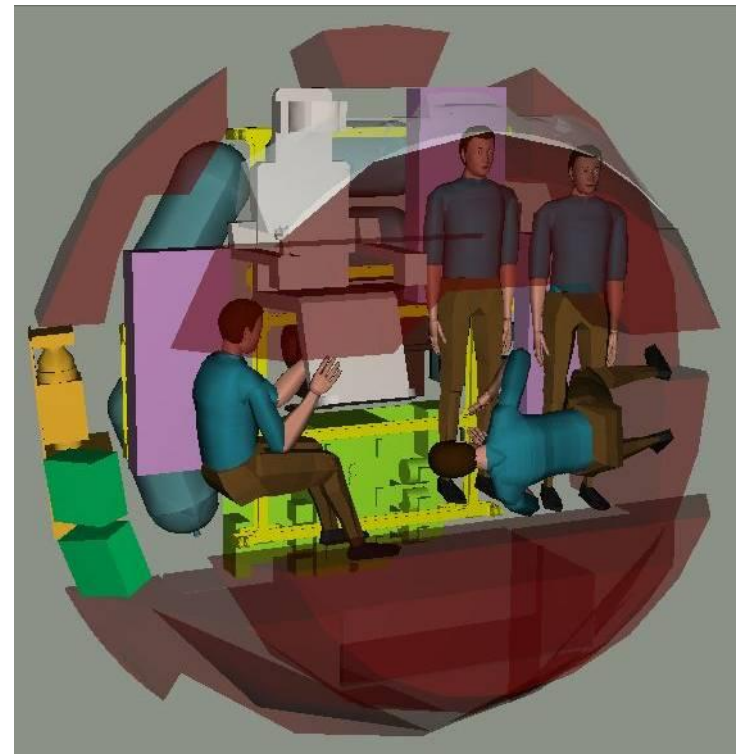
Rendezvous/ Docking – It is assumed that a crew member will adjust their position to allow for visibility through the hatch window to assist rendezvous and docking operations.



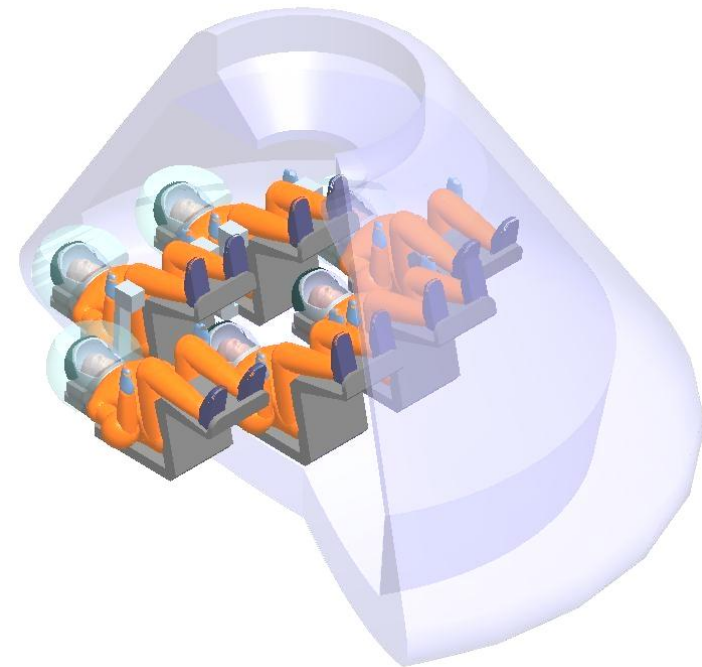
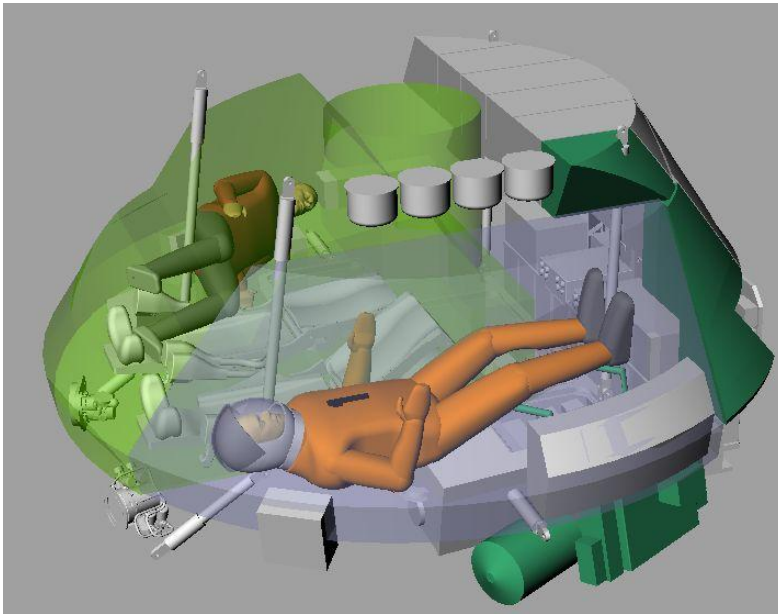
Post Insertion – All crew members have stowed their respective seats and suits. Access to waste and hygiene is now possible and the crew is ready to perform in-flight tasks.



Post Sleep – Potential activities include food preparation, review flight plan/execute pack, housekeeping/filter cleaning, and personal hygiene.



- Computer modeling analysis confirmed that there was adequate volume for unsuited scenarios and suit donning/doffing activity
 - Seats, suit design stowage and waste hygiene activities noted to be critical volume drivers





CASE STUDY: Human-in-the-Loop Evaluation Approach

Crew Exploration Vehicle (CEV)

- Participants:
 - Nine stakeholders and ten crewmembers participated in the unsuited evaluations
 - Six crewmembers also participated in a suited evaluation
- A physical mock-up was outfitted with volumetric representations of systems such as seats, and stowage bags
 - Design for suits, seats and other key systems do not yet exist for CEV
 - Notional placeholders such as existing space suit and seat prototype concepts were used in the mock-up
- Thirteen scenarios were developed to represent mission/crew tasks and considered to be primary volume drivers for the CEV
 - Unsuited evaluations included a structured walkthrough of these tasks such as suit stowage, waste hygiene activity, trash stowage, sleep, and 36-hour rescue (land/water)
 - Suited evaluations included timed donning of the existing launch and entry suit to simulate a contingency scenario followed by doffing/ stowing of the suits
- All mockup evaluations were videotaped
- Structured questionnaires were used to document user interface issues and impacts of layout configuration on volume

- Initial evaluation showed that NHV would support crew of 6
- NHV of the current design accommodated task-based scenarios evaluated



- Current design NHV accommodated space suit donning for a crew of 6
 - One should plan for volume of a minimum 2 crew helpers and 1 crewmember being donned in one volume area
 - Doffing → Only limitation was that a crewmember needed his/her full body length to doff the suit





- Human-in-the-loop evaluations also confirmed that there was adequate volume for unsuited scenarios and suit donning/doffing activity
- Additional comments from crew and stakeholders on internal cabin layout:
 - Seats → provide stowage volume for gloves, personal items & possibly the suit
 - Suit Stowage → stow individually and possibly integrate it into seat
 - Consumables → Multiple means of access to consumable stowage volume (e.g., access from side and below stowage volume)
 - Sleep → Simplified (shuttle) bag with less volume/weight; need to access to toilet
 - Restraints → Egress/Ingress handholds/footholds by hatch/tunnel, mobility aids for crewmember during seat egress in 1g, flexible straps for temporary stowage and mobility aids
 - Rescue-water landing → Sick bags/water should be handy



Near-Term Plan

Crew Exploration Vehicle (CEV)

- In 2007, NASA and Lockheed Martin will conduct additional NHV studies of the most recent CEV design configuration(s) as the design matures
 - Computer modeling and analyses
 - Physical measurements of mockup hardware
 - Human in the loop task evaluations
- Based on these studies, verification methods for the NHV requirement will be planned and documented
 - Master Verification Plan
 - Verification Information Sheets



In Conclusion...

Crew Exploration Vehicle (CEV)

- HE System team has been key to ensuring
 - Human is treated as a “system” with key functions, requirements, and interfaces to vehicle systems
 - HE is involved early in the design process
- The low-fidelity mock-up evaluations along with human modeling analysis generated discussions that:
 - led to high-level systems requirements and human-centered design decisions
 - Habitable volume is a key enabler of the human system’s ability to meet its requirements safely, and effectively accomplish mission goals
 - allowed HE requirements and operational concepts to evolve in parallel with engineering system concepts and design requirements
 - Habitable volume should be managed as an integrated system (considering stowage, equipment, and fixed and reconfigurable vehicle structures)
 - Translation corridors within the habitable volume must be established to reduce crew risk during a contingency such as pad egress, fire or off-nominal landing

BOTTOM LINE: Continued HE involvement will ensure a structured approach to human-centered CEV design.



THANK YOU!

